Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

VARIABILITY AND AUTOTOMY OF PHATARIA.

BY SARAH P. MONKS.

Phataria (*Linckia*) *unifascialis* Gray, var. *bifascialis* is a starfish that is remarkable for the variability in the size and number of its rays. Regularity is the exception. In over 400 specimens examined not more than four were symmetrical and no two were alike. Fig. 13, Pl. XLII, is a nearly symmetrical six-rayed star, but one of its rays has been broken off and renewed.

The plate shows the great variability in size of stars, number of rays and different breaking places.

The animals vary in size from four to seventeen centimeters. This difference may in some measure be due to age, but there is evidently also considerable difference in size in adult specimens.

The normal number of rays is five, but some specimens have only one, while others have four, six, seven, or even nine; four, five or six being most common numbers. Of 248 specimens examined 29 had one ray, 34 four rays, 135 five rays, 44 six rays, 5 seven rays and 1 nine rays.

There is a marked irregularity in the size of the rays, for the breaking and renewing occur at all ages, or, at least, at all sizes. Single living rays without any external sign of disk are not uncommon. Twenty-two in a lot of 240 were single. In animals measured the rays varied in length from 22–75 mm., and were in all conditions, from specimens which showed by the raw surface that the breakage was recent, through all grades of healing surfaces to stars where new rays appeared as mere buds, to the comet series and to the various rays of adult Phatariæ.

Comets are frequently found; there were forty-one of them in 240 specimens. These are stars with one long ray and a number of small rays extending from a minute disk. They are rays that have made a new body. In Pl. XLII, 3–11 are comets. The long ray is from 2–7 cent. in length. On account of their small size the single rays and comets are more easily overlooked by collectors.

This species of *Phataria* is mottled reddish-brown and ash color, with the tips of the rays and the small new rays, or new portion of the ray, a brighter and uniform red. It is easy to distinguish new parts by this growth "color," even when the line of breakage is obliterated.

From the great discrepancy in the size of the rays it follows that one or two rays may be sexually mature, while others are small or even buds. In two individuals sexually mature August 4, 1901, the measurements of rays show: ♂, 77.70.58.20 mm.; ♀, 70.65.52.13 mm.

This species generally has two or more madreporites and two or more ani.

There is a great difference in the size of the madreporic body and frequently, but not always, it is larger in large specimens. In 174 specimens 6 had one, 154 had two, 11 had three, 2 had four and 1 had five madreporites.

The ani are only visible in live animals. In 68 specimens 15 had one, 48 had two, 3 had three, 1 had four ani.

There may be some connection, as has been suggested, between madreporites and breaking plane, but I have failed to find anything satisfactory on the subject. Sometimes the largest ray, or a large ray, is between two madreporic bodies. In 132 specimens 87 long arms and 45 short arms were between the madreporites.

There is a further irregularity in this species in the place from which the reproductive material finds exit. Usually in asteroids it comes from the angle between rays, but in *Phataria* the sperm and ova may come from any part of the inner two-thirds of a ray.

I have also found this year (August, 1904) that a *Phataria* may have two mouths. In fig. 22 there is a mouth at each meeting point (*A* and *B*) of the ambulacral furrows. In No. 11 there are also indications of two mouths, and in another specimen I have, but owing to the rareness of the peculiarity I have not wished as yet to destroy these two specimens in order to prove the surmise.

The want of symmetry in this *Phataria* suggests the belief that the ability to break and regenerate is greater in this species than in ordinary Asteroidea, and that it is a common factor in the life of the species. Most starfish can lose their rays and make new ones, but it is a generally accepted opinion among zoologists that a ray cannot make a new body unless some portion of the disk is present. In *P. bifascialis* Gr. there is a suggestion that a ray can regenerate a body, although the evidence is inconclusive. The suggestion is seen in the series of figs. 1–11 in the plate.[1]

---

[1] Since writing the above in 1901 I have been fortunate in a series of experiments extending to the present time, August, 1904, in having a number of single rays, cut at various places, regenerate the disk and other rays. I cut off rays, and in that way the stretching of the pyloric cæca and the consequent loss of

This suggestion springs from various facts: The extent of the "growth color" in comets, the apparent absence of disk in single rays, and the constant place of breaking in the pyloric cæca.

The breaking place in the skeleton may occur near the disk, from 6–12 mm. from the angle of the ray, or at almost any point on the ray. I have never seen a break that was decidedly inside the disk.

In 18 specimens with 26 regenerating rays, 4 were less than 3 mm., 20 were from 3–6 mm., and 2 were 35 and 45 mm. from angle.

The cause of breaking is obscure. Unlike Ophiurians they are exceedingly tough. At touch *Phataria* becomes hard, tough and rigid, and when it is thus contracted it requires considerable strength to pull it asunder, and it is a difficult matter even to cut among the ossicles.

If any external force bears a part in breaking the animal it is probable that the creature is surprised when limp and relaxed, but I am inclined to think that *Phataria* always breaks itself, no matter what may be the impulse. They may break when conditions are changed, sometimes within a few hours after being placed in jars, or a few days, or even not for months. Some never break, but stand all kinds of inconvenience of heat and cold and stagnant water.

There is no season for the breaking, for they are found newly broken in the sea in all seasons of the year. The sensitiveness of this species to our cold spells in winter and hot spells in summer has put an end to many promising experiments. Whatever may be the stimulus the animal can and does break of itself.

During the years 1901–04 I have watched more than fifty starfish disunite. There is a regularity about the matter that indicates that the breaking is not an accident, or the fancy of a day, but a habit of the species. The breaking is automatic. Experiment confirms the inference that naturally arises on seeing a large number of specimens together that the irregularity is due to an inherent character of this species of *Phataria*. The process is deliberate. It is not a breaking in the proper sense of the word, but a drawing or pulling asunder. It requires from half an hour to three or four hours, with resting spells, and the motions are perceptible.

The ordinary method is for the main portion of the starfish to remain fixed and passive with the tube feet set on the side opposite the departing ray, and for this ray to walk slowly away at right angles to

---

time for its withdrawal were avoided and after a number of months the ray had reached the comet stage. In one case two arms started to grow from the place from which one had been cut. The photograph and statement of facts appeared in *Proc. Acad. Nat. Sci. Phila.*, May, 1904.

the body, to change position, twist, and do all the active labor necessary to the breakage. If there are more rays than are needed to resist the pulling arm they take a negative part and position. Frequently they hang limp with their ambulacræ withdrawn.

There seems to be the same coördination in this work as in the walking of Asteroidea, for in the six or eight positions taken during the severing of a ray the larger portion of the star always keeps pulling in a direction opposite that of the parting ray, and not in any, or all, of the four, five or six directions of radiation.

The skeleton breaks in one of two ways. In one way the ray swells about its midpoint and grows smaller at its proximal portion as it pulls away from the body. In the region of strain the ossicles become separated for a space of about 25 mm., so that the white connective and muscular tissues shine between them till finally, just before parting, they stand out like beads on a network of shiny white floss. There is much more elasticity in the animal at this time than would seem possible in a starfish.

Immediately after the break the ossicles recover their compact position and the two parted edges show a more or less jagged surface. This way is rapid, the body wall being pulled apart in from three to thirty minutes after the arm becomes narrowed.

In the other way of breaking only a small area is affected by the strain, and the breaking place shows from the first as a fracture. There is no narrowing of the ray, no strained surface and no gradual separation of ossicles. A small opening, something like a crack, appears on the dorsal side of the ray, and this increases with an uneven edge till the body wall is parted around the entire ray. The first visible evidence of this kind of division is, either the ray is in a strained position opposite the body or it lops over and hangs limp, letting its weight act as the pulling power. The invariable method in *Phataria* I have watched, after the body wall breaks, is: The arm walks away; the pyloric cæca are pulled out of the arm, sometimes for 83 mm., and kept very tense; then a break occurs in the tube connecting the pyloric cæca with the stomach; the pyloric cæca are withdrawn into the arm and the small portion of the tube into the body and the arm is free. The parting of the soft tissues is not abrupt, is accomplished by sundering strands thread by thread. The pyloric cæca and tube are wonderfully elastic. Sometimes the tube is stretched till it appears as the finest thread.

After breaking the pyloric cæca coil up, and as they are retracted to their ordinary position an occasional spasmodic jerk is seen in them.

Sometimes they are withdrawn immediately, but frequently an arm crawls around for hours, or days, trailing the cæcum till it is withdrawn or falls away.

Probably if the cæca are not taken in within a few hours the muscles ose their elasticity and the cæca decay and drop off. Occasionally these organs are left on the disk and sometimes the tube is broken in such a manner as to leave them hanging like two coiled trails. After freeing itself the ray crawls up the glass and stations itself with the broken part downward and remains so for a long time. This is the attitude of a single ray till all, or nearly all, the pyloric cæcum assumes its normal position.

After one arm is separated, or even when it is going, another may break away. I saw one animal try to break the disk apart after having lost two rays. It took many positions, strained the tissues and worked for hours, but died before the disk was broken.

The results of my observations are: The breaking is automatic and is effected by pulling apart or fracture without strain; there is coördination of parts in producing the separation; the tissues relax at the plane of rupture; this plane may be near the disk or a variable distance from it on the ray; the pyloric cæca are always pulled out and much stretched; the break of the cæcum occurs at the tube connecting the stomach and glandular portion; the pyloric cæcum is generally taken back into the arm; the severed ray may live more than a week, even under adverse circumstances, without signs of regeneration; and, from my experiments extending over a period of three years, I have found that rays cut various distances from the disk make disks, mouths and new rays in about six months.

Explanation of Plate XLII.

The plate shows growth-series and comets; variability in number and size of rays, in size of animal and in breaking places; color distribution and general characteristics of species; and all except figs. 17 and 18 are as they were found.

Fig. 1.—Side view, recently healed.

Fig. 2.—Oral view, showing growing down of aboral surface. This also shows in fig. 7.

Fig. 3.—Oral view, new rays and mouths.

Figs. 3–10.—Comets.

Fig. 11.—Eight new rays, probably two mouths.

Figs. 12 and 15.—Five-rayed, showing new arms as "buds."

Figs. 14 and 16.—Four-rayed; fig. 16 shows color arrangement.

Figs. 17 and 18.—Cut '03 and died '04, a new ray on fig. 17 and a new body on fig. 18.

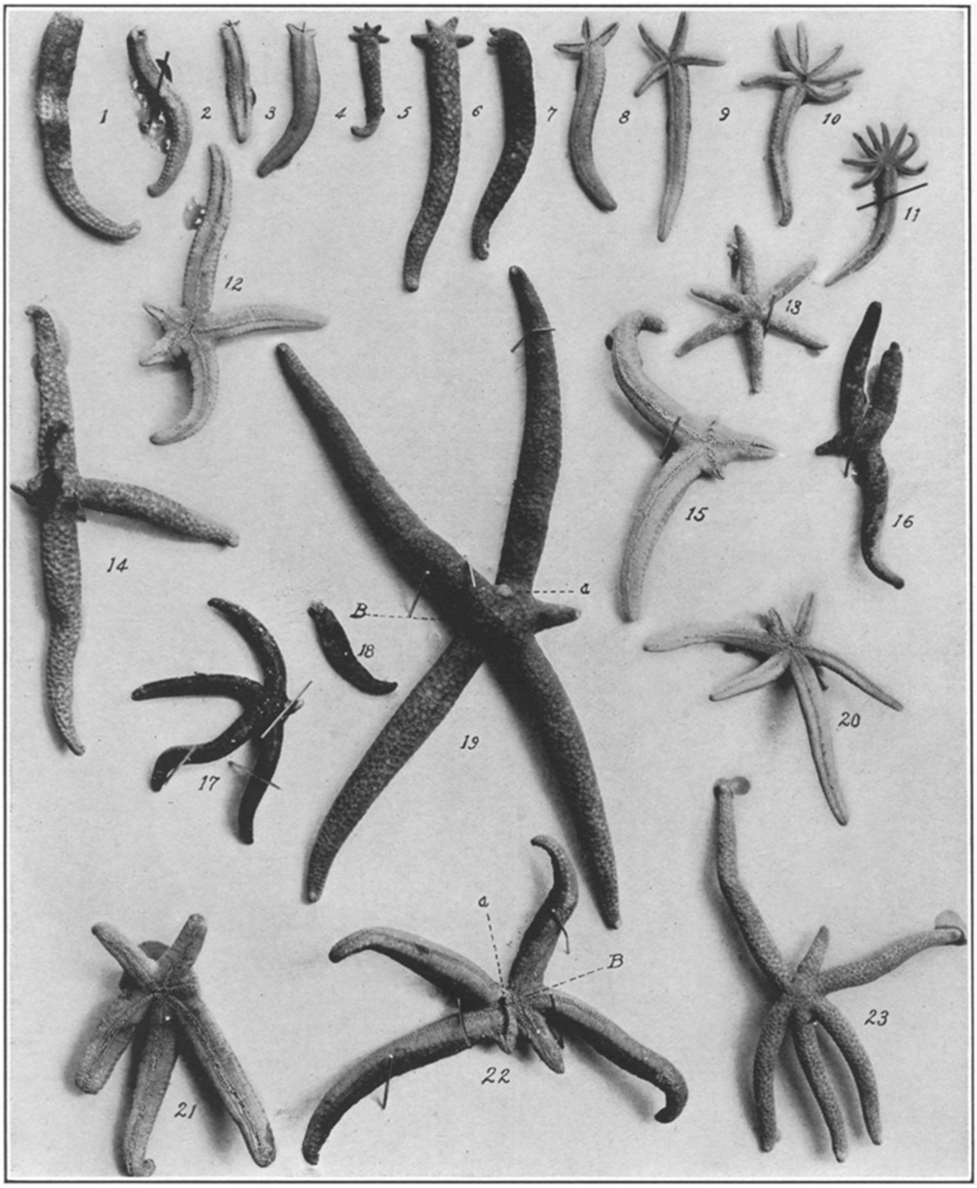
Fig. 19.—A large *Phataria* with 2 madreporites, *A* and *B*.

Figs. 13 and 20.—Twenty-three six-rayed.

Fig. 21.—Shows four distinct break planes and has only one good ray. This is a type of the thick specimens.

Fig. 23.—Is a type of the thin species.

Fig. 22.—Shows two mouth places, *A* and *B*.



MONKS ON PHATARIA.